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2705/302
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STRUCTURES III
Oct./Nov. 2018
Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN BUILDING TECHNOLOGY
DIPLOMA IN ARCHITECTURE

MODULE III

STRUCTURES III

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

- Answer booklet;*
- Drawing instruments;*
- Drawing paper size A3;*
- Mathematical tables/Scientific calculator.*

This paper consists of EIGHT questions.

Answer any FIVE questions.

All questions carry equal marks.

Maximum marks for each part of a question are indicated.

Candidates should answer the questions in English.

This paper consists of 10 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

1.

Assuming a unit load moving from A to B on the girder shown in figure 1 below, draw the influence line diagrams indicating values at two metre intervals for the following:

- (a) Reaction A;
- (b) Reaction B;
- (c) Shear force at point C;
- (d) Bending moment at point C.



Fig. 1

(20 marks)

2.

Using moment distribution method, analyse the frame shown in figure 2 and hence draw the bending moment diagram indicating values at critical points.

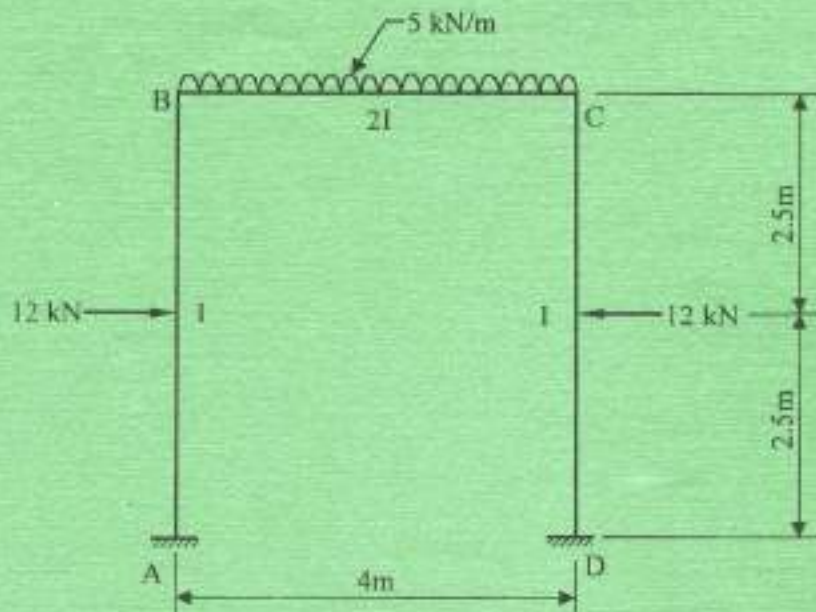


Fig. 2

(20 marks)



3. Using the three moment theorem, analyse the beam in figure 3 and hence:

- draw the bending moment diagram indicating values at critical points;
- determine the reactions at the supports.

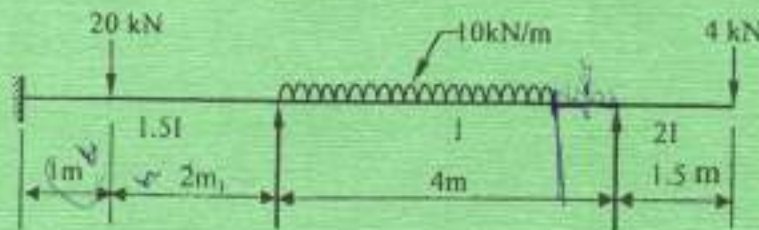


Fig. 3

(20 marks)

4. A universal beam section is to be used under the loading conditions shown in figure 4 below. If you are limited to a $533 \times 210 \times 122$ kg/m UB, $457 \times 191 \times 82$ kg/m UB and $457 \times 152 \times 60$ kg/m UB, select the most suitable section from the three, and hence check its adequacy in:

- bending ULS;
- shear ULS;
- deflection SLS.

Take: $E = 205 \text{ kN/mm}^2$

Assume that the beam is fully restrained laterally and the material is in grade 43 steel.

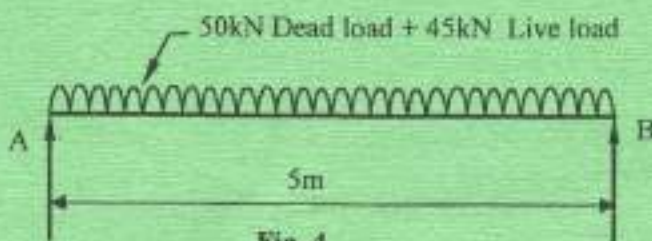


Fig. 4

NOTE: Dead load is inclusive of self weight of section.

(20 marks)

5. Using the data provided below, design a suitable size for the timber joist marked X-X shown in figure 5 and hence check for shear and bearing.

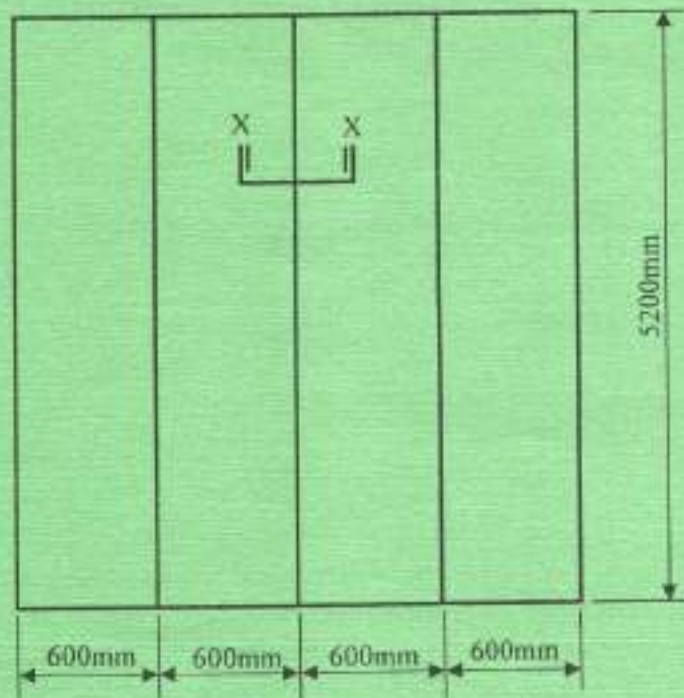


Fig. 5

Data:

- Dead load inclusive of self weight = 1.2 kN/m²
 Dead load inclusive of imposed load = 1.0 kN/m²

Grade stresses

- bending parallel to grain - 7.5 N/mm²
- shear parallel to grain - 0.71 N/mm²
- compression perpendicular to grain - 1.90 N/mm²

- Depth of section = 2 x breadth
 Length of bearing at support = 100 mm

Assume medium term loading.

Take:

$$K3 = 1.25$$

$$K8 = 1.1$$

Assume any other relevant information.

(20 marks)

6. Check the suitability of the $203 \times 203 \times 52$ kg/m universal column, loaded as shown in figure 6; if both ends are restrained in position and direction. Assume grade 43 steel.

Take $m = 1$ (neglect the self-weight of the column).

(20 marks)

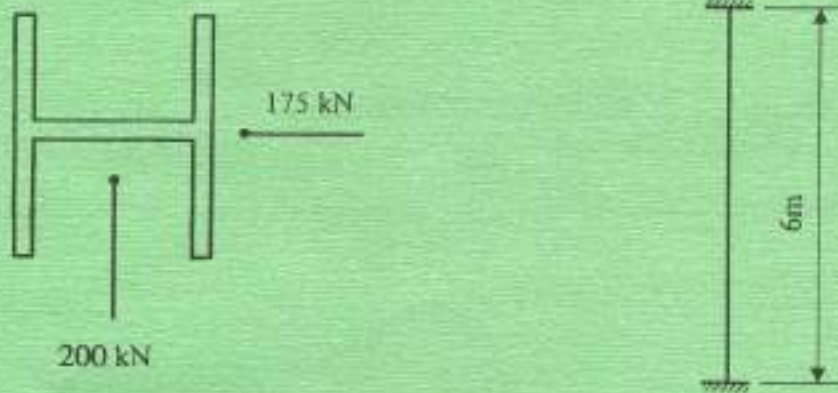


Fig. 6



7. (a) (i) Sketch and name any four butt welds.

(ii) With the aid of a diagram illustrate the following on a fillet weld:

- leg length;
- throat.

(8 marks)

(b) Design the balanced 8 mm fillet weld for the gusset connection shown in figure 7, if it is not to go round the corners. Take weld strength as 215 N/mm run .

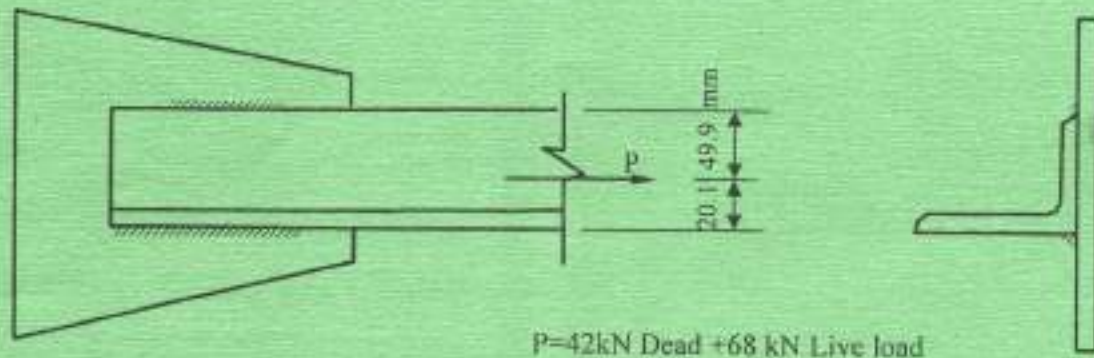


Fig. 7

$P = 42 \text{ kN Dead} + 68 \text{ kN live loads.}$

(12 marks)

8. Using moment distribution method, analyse the beam shown in figure 8 and hence:
- calculate the reactions;
 - draw the bending moment diagram indicating values at all critical points.

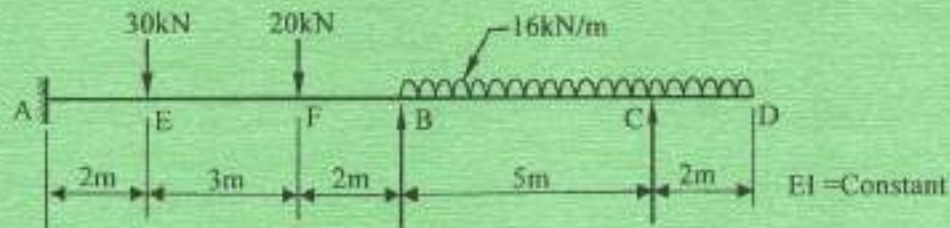


Fig. 8

$EI = \text{constant.}$

(20 marks)



Table 1 – Universal beams (abstracted from the *Steework Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(a) Dimensions

Serial size	Mass per metre (kg)	Depth of section D (mm)	Width of section B (mm)	Thickness		Root radius r (mm)	Depth between fllets d (mm)	Ratio for local buckling		Dimensions for detailing			Surface area	
				Web t (mm)	Flange T (mm)			Flange b/T	Web d/t	End clearance C (mm)	Notch N (mm)	a (mm)	Per metre (m ²)	per tonne (m ²)
531 x 310	122	544.6	211.9	12.8	21.3	12.7	416.5	4.97	37.2	8	110	36	1.89	15.5
	109	539.5	210.7	11.6	18.8	12.7	416.5	5.60	41.1	8	110	32	1.88	17.2
	101	536.7	210.1	10.9	17.4	12.7	416.5	6.04	43.7	7	110	32	1.87	18.5
	92	533.1	209.3	10.2	15.8	12.7	416.5	6.71	46.7	7	110	30	1.86	20.3
	82	528.3	208.7	9.6	13.2	12.7	416.5	7.91	49.6	7	110	26	1.85	22.6
457 x 191	98	467.4	192.8	11.4	19.6	10.2	407.9	4.92	35.8	8	102	30	1.87	17.0
	89	463.6	192.0	10.6	17.7	10.2	407.9	5.42	38.5	7	102	28	1.86	18.6
	82	460.2	191.3	9.9	16.0	10.2	407.9	5.98	41.2	7	102	28	1.85	20.1
	74	457.2	190.5	9.1	14.5	10.2	407.9	6.57	44.8	7	102	26	1.84	22.2
	67	453.6	189.9	8.3	12.7	10.2	407.9	7.48	48.0	6	102	24	1.83	24.4
457 x 152	82	465.1	153.5	10.7	18.9	10.2	407.0	4.06	38.0	7	82	30	1.51	18.4
	74	461.3	152.7	9.9	17.0	10.2	407.0	4.49	41.1	7	82	28	1.50	20.2
	67	457.3	151.9	9.1	15.0	10.2	407.0	5.06	44.7	7	82	26	1.49	22.2
	60	454.7	152.9	8.0	13.3	10.2	407.0	5.73	51.0	6	84	24	1.49	24.8
	52	449.8	152.4	7.6	10.9	10.2	407.0	6.99	53.6	6	84	22	1.48	28.4

Table 2 – Universal columns (abstracted from the *Steework Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(a) Dimensions

Serial size	Mass per metre (kg)	Depth of section D (mm)	Width of section B (mm)	Thickness		Root radius r (mm)	Depth between fllets d (mm)	Ratio for local buckling		Dimensions for detailing			Surface area	
				Web t (mm)	Flange T (mm)			Flange b/T	Web d/t	End clearance C (mm)	Notch N (mm)	a (mm)	Per metre (m ²)	per tonne (m ²)
356 x 406	834	474.7	424.1	47.6	77.0	15.2	290.2	2.75	6.10	26	200	94	2.52	3.98
	551	455.7	418.1	42.0	67.5	15.2	290.2	3.10	6.91	23	200	84	2.48	4.49
	467	436.6	412.4	35.9	58.0	15.2	290.2	3.56	8.08	20	200	74	2.47	5.19
	393	419.1	407.0	30.6	49.2	15.2	290.2	4.14	9.48	17	200	66	2.38	6.05
	340	406.4	403.0	26.5	42.9	15.2	290.2	4.70	11.0	15	200	60	2.30	6.90
	287	392.7	399.0	22.6	36.5	15.2	290.2	5.47	12.8	13	200	52	2.31	8.06
235	381.6	395.0	18.5	30.2	15.2	290.2	6.54	15.7	11	200	46	2.28	9.70	
COLCORE	477	437.0	424.4	48.0	53.2	15.2	290.2	3.99	6.05	26	200	70	2.43	5.09
356 x 368	302	374.7	374.4	16.9	27.0	15.2	290.2	6.93	17.3	10	190	44	2.19	10.8
	177	368.3	372.1	14.5	23.8	15.2	290.2	7.82	20.0	9	190	40	2.17	12.3
	153	362.0	370.2	12.6	20.7	15.2	290.2	8.94	23.0	8	190	36	2.15	14.1
	129	355.6	368.3	10.7	17.5	15.2	290.2	10.5	27.1	7	190	34	2.14	16.6
305 x 305	283	365.3	321.8	26.9	44.1	15.2	246.6	3.65	9.37	13	158	60	1.94	6.85
	240	352.6	317.9	23.0	37.7	15.2	246.6	4.22	10.7	14	158	54	1.90	7.93
	198	339.9	314.1	19.2	31.4	15.2	246.6	5.00	12.8	12	158	48	1.87	9.45
	158	327.2	310.6	15.7	25.0	15.2	246.6	6.21	15.7	10	158	42	1.84	11.6
	137	320.5	308.7	13.8	21.7	15.2	246.6	7.11	17.9	9	158	38	1.82	13.3
	118	314.5	306.8	11.9	18.7	15.2	246.6	8.20	20.7	8	158	34	1.81	15.3
	97	307.8	304.8	9.9	15.4	15.2	246.6	9.90	24.9	7	158	32	1.79	18.4
254 x 254	167	289.1	264.5	19.2	31.7	12.7	200.3	4.17	10.4	12	134	46	1.58	9.44
	132	276.4	261.0	15.8	25.3	12.7	200.3	5.16	12.8	10	134	40	1.54	11.7
	107	266.7	258.3	13.0	20.5	12.7	200.3	6.30	15.4	9	134	34	1.52	14.2
	89	260.4	255.9	10.5	17.3	12.7	200.3	7.40	19.1	7	134	32	1.50	16.9
	73	254.0	254.0	8.6	14.2	12.7	200.3	8.84	23.3	6	134	28	1.48	20.3
203 x 203	84	272.3	208.8	13.0	20.5	10.2	160.9	5.09	12.4	9	108	32	1.24	16.4
	71	215.9	206.2	10.3	17.3	10.2	160.9	5.96	15.6	7	108	28	1.22	17.2
	60	209.6	205.2	9.3	14.2	10.2	160.9	7.23	17.3	7	108	26	1.20	20.1
	52	206.2	203.9	8.0	12.5	10.2	160.9	8.16	20.1	6	108	24	1.19	23.0
	46	203.2	203.2	7.3	11.0	10.2	160.9	9.24	22.0	6	108	22	1.19	25.3
152 x 152	37	161.8	154.4	8.1	11.5	7.6	123.5	6.71	15.2	6	84	20	0.912	24.6
	30	157.5	152.9	6.6	9.4	7.6	123.5	8.13	18.7	5	84	18	0.9	30.0
	23	152.4	152.4	6.1	6.8	7.6	123.5	11.2	20.2	5	84	16	0.889	34.7

Table 1 – Universal beams continued (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(b) Properties

Designation		Second moment of area		Radius of gyration		Elastic modulus		Plastic modulus		Buckling parameter	Torsional index	Warping constant	Torsional constant	Area of section
Serial size	Mass per metre	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	μ	λ	W	J	A
(mm)	(kg)	(cm ⁴)	(cm ⁴)	(cm)	(cm)	(cm ²)	(cm ²)	(cm ³)	(cm ³)			(dm ⁶)	(cm ⁴)	(cm ²)
533 x 210	122	76 200	3 390	22.1	4.67	2 800	320	1 200	501	0.876	27.6	2.32	180	156
	109	66 700	2 940	21.9	4.60	2 470	279	2 820	435	0.875	30.9	1.99	126	139
	101	61 700	2 690	21.8	4.56	2 300	257	2 620	400	0.874	33.1	1.82	102	129
	92	55 400	2 390	21.7	4.51	2 080	229	2 370	356	0.872	36.4	1.60	76.2	118
457 x 191	82	47 500	2 010	21.3	4.38	1 800	192	2 060	300	0.865	41.6	1.33	51.3	104
	98	45 700	2 340	19.1	4.33	1 960	243	2 230	378	0.88	25.8	1.17	121	125
	89	41 000	2 090	19.0	4.28	1 770	217	2 010	338	0.879	28.3	1.04	90.5	114
	82	37 100	1 870	18.8	4.23	1 610	196	1 830	304	0.877	30.9	0.923	69.2	105
	74	33 400	1 670	18.7	4.19	1 460	175	1 660	273	0.876	33.9	0.819	52.0	95.0
67	29 400	1 450	18.5	4.17	1 300	153	1 470	237	0.873	37.9	0.706	37.1	85.4	
457 x 152	82	36 200	1 140	18.6	3.31	1 560	149	1 800	235	0.872	27.3	0.569	89.3	104
	74	32 400	1 010	18.5	3.26	1 410	133	1 620	209	0.87	30.0	0.499	66.6	95.0
	67	28 600	878	18.3	3.21	1 250	116	1 440	182	0.867	33.6	0.429	47.5	85.4
	60	25 900	794	18.3	3.23	1 120	104	1 280	163	0.869	37.5	0.387	33.6	75.9
	52	21 300	645	17.9	3.11	949	84.6	1 090	133	0.859	43.9	0.311	21.3	66.5

Table 2 – Universal columns continued (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(b) Properties

Designation		Second moment of area		Radius of gyration		Elastic modulus		Plastic modulus		Buckling parameter	Torsional index	Warping constant	Torsional constant	Area of section
Serial size	Mass per metre	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	μ	λ	W	J	A
(mm)	(kg)	(cm ⁴)	(cm ⁴)	(cm)	(cm)	(cm ²)	(cm ²)	(cm ³)	(cm ³)			(dm ⁶)	(cm ⁴)	(cm ²)
356 x 406	634	275 000	98 200	18.5	11.0	11 600	4630	14 200	7110	0.843	5.46	38.8	13 700	808
	551	227 000	82 700	18.0	10.9	9 960	3950	12 100	6060	0.841	6.05	31.1	9 240	702
	467	183 000	67 900	17.5	10.7	8 390	3290	10 000	5040	0.839	6.66	24.3	5 820	595
	393	147 000	55 400	17.1	10.5	7 000	2720	8 230	4160	0.837	7.86	19.0	3 550	501
	340	122 000	46 800	16.8	10.4	6 030	2320	6 990	3540	0.836	8.85	15.5	2 340	433
	287	100 000	38 700	16.5	10.3	5 080	1940	5 820	2950	0.835	10.2	12.1	1 440	366
	235	79 100	31 000	16.2	10.2	4 150	1570	4 690	2380	0.834	12.1	9.54	812	300
COLCORE 477	172 000	68 100	16.8	10.6	8 080	3210	9 700	4980	0.815	6.91	23.8	5 700	607	
356 x 368	262	66 300	23 600	16.0	9.57	3 540	1260	3 980	1920	0.844	13.3	7.14	560	238
	177	37 200	20 500	15.9	9.52	3 100	1100	3 460	1670	0.844	15.0	6.07	383	226
	153	48 500	17 500	15.8	9.46	2 680	944	2 960	1430	0.844	17.0	5.09	251	193
	129	40 200	14 600	15.6	9.39	2 260	790	2 480	1200	0.843	19.9	4.16	153	163
305 x 305	283	78 800	34 500	14.8	8.25	4 310	1530	5 100	2340	0.855	7.65	6.33	2 030	360
	240	64 200	20 200	14.5	8.14	3 640	1270	4 250	1950	0.854	8.73	5.01	1 270	306
	198	50 800	16 200	14.2	8.02	2 990	1030	3 440	1580	0.854	10.2	3.86	734	252
	158	38 700	13 500	13.9	7.89	2 370	806	2 680	1230	0.852	12.5	2.86	379	201
	137	32 800	10 700	13.7	7.82	2 050	691	2 300	1050	0.851	14.1	2.38	250	175
	118	27 600	9 010	13.6	7.75	1 760	587	1 950	892	0.851	16.2	1.97	160	150
	97	22 200	7 270	13.4	7.68	1 440	477	1 590	723	0.850	19.3	1.55	91.1	123
254 x 254	167	29 900	9 800	11.9	6.79	2 070	741	2 420	1130	0.852	8.49	1.62	625	212
	132	22 600	7 520	11.6	6.67	1 630	576	1 870	879	0.850	10.3	1.18	322	169
	107	17 500	5 900	11.3	6.57	1 310	457	1 490	693	0.848	12.4	0.894	173	137
	89	14 300	4 830	11.2	6.52	1 100	379	1 230	573	0.849	14.4	0.716	104	114
	73	11 400	3 870	11.1	6.46	894	305	989	462	0.849	17.3	0.557	57.3	92.9
203 x 203	86	9 460	3 130	9.27	5.32	851	299	979	456	0.85	10.2	0.317	138	110
	71	7 650	2 540	9.16	5.28	708	246	802	374	0.852	11.9	0.25	81.5	91.1
	60	6 090	2 040	8.96	5.19	581	199	632	301	0.847	14.1	0.195	46.6	75.8
	52	5 260	1 770	8.90	5.16	510	174	568	264	0.848	15.8	0.166	32.0	66.4
	46	4 560	1 540	8.81	5.11	449	151	497	230	0.846	17.7	0.142	22.2	58.8
152 x 152	37	2 220	709	6.84	3.87	274	91.8	310	140	0.848	13.3	0.04	19.5	47.4
	30	1 740	558	6.75	3.82	221	73.1	247	111	0.848	16.0	0.0306	10.5	38.2
	23	1 260	403	6.51	3.68	166	52.9	184	80.9	0.837	20.4	0.0214	4.87	29.8



Table 3 — Compressive strength p_c (N/mm²) (continued)

b) Values of p_c (N/mm²) with $\lambda < 110$ for strut curve b

$\lambda \times 10^3$	Steel grade and design strength p_y (N/mm ²)														
	S 275					S 355					S 460				
	235	245	255	265	275	315	325	335	345	355	400	410	430	440	460
15	235	245	255	265	275	315	325	335	345	355	399	409	428	438	457
20	234	243	253	263	272	310	320	330	339	349	391	401	420	429	448
25	229	239	248	258	267	304	314	323	332	342	384	393	411	421	439
30	225	234	243	253	262	298	307	316	325	335	375	384	402	411	429
35	220	229	238	247	256	291	300	309	318	327	366	374	392	400	417
40	216	224	233	241	250	284	293	301	310	318	355	364	380	388	404
42	213	222	231	239	248	281	289	298	306	314	351	359	375	383	399
44	211	220	228	237	245	278	286	294	302	310	346	354	369	377	392
46	208	218	226	234	242	275	283	291	298	306	341	349	364	371	386
48	207	216	223	231	239	271	279	287	294	302	336	343	358	365	379
50	205	213	221	229	237	267	275	283	290	298	330	337	351	358	372
52	203	210	218	226	234	264	271	278	286	293	324	331	344	351	364
54	200	208	215	223	230	260	267	274	281	289	318	325	337	344	356
56	198	205	213	220	227	256	263	269	276	283	312	318	330	336	347
58	196	202	210	217	224	252	258	265	271	278	305	311	323	328	339
60	193	200	207	214	221	247	254	260	266	272	298	304	314	320	330
62	190	197	204	210	217	243	249	255	261	268	291	296	306	311	320
64	187	194	200	207	213	238	244	249	255	261	284	289	298	303	311
66	184	191	197	203	210	233	239	244	249	255	276	281	289	294	301
68	181	188	194	200	206	228	233	239	244	249	269	273	281	285	292
70	178	185	190	196	202	223	228	233	238	243	261	266	272	276	282
72	175	181	187	193	198	218	223	227	232	236	254	257	264	267	273
74	172	178	183	189	194	213	217	222	226	230	246	249	255	258	264
76	169	175	180	185	190	208	212	216	220	223	238	241	247	250	255
78	166	171	176	181	186	203	206	210	214	217	231	234	239	241	246
80	163	168	172	177	181	197	201	204	208	211	224	226	231	233	237
82	160	164	169	173	177	192	196	199	202	205	217	219	223	225	229
84	156	161	166	169	173	187	190	193	196	199	210	212	216	218	221
86	153	157	161	165	169	182	185	188	190	193	203	205	208	210	213
88	150	154	158	161	165	177	180	182	185	187	196	198	201	203	206
90	146	150	154	157	161	172	175	177	179	181	190	192	195	196	199
92	143	147	150	153	156	167	170	172	174	176	184	185	188	189	192
94	140	143	147	150	152	162	165	167	169	171	178	179	182	183	185
96	137	140	143	146	148	158	160	162	164	165	173	173	176	177	179
98	134	137	139	142	145	153	155	157	159	160	167	168	170	171	173
100	130	132	135	138	141	149	151	152	154	155	161	162	164	165	167
102	127	129	132	135	137	145	146	148	149	151	156	157	159	160	162
104	124	127	129	131	133	141	142	144	145	146	151	152	154	155	156
106	121	124	126	128	130	137	138	139	141	142	147	148	149	150	151
108	118	121	123	125	126	133	134	135	137	138	142	143	144	145	147

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Table 4 – Compressive strength p_c (N/mm²) (continued)

5) Values of p_c (N/mm²) with $\lambda < 110$ for strut curve c

λ_y	Steel grade and design strength p_y (N/mm ²)														
	S 275					S 355					S 460				
	275	245	255	265	276	315	325	335	345	355	400	410	430	440	460
16	235	245	255	265	276	315	325	335	345	355	398	408	427	436	455
20	223	242	252	261	271	308	317	326	336	345	387	396	414	424	442
25	226	236	245	254	263	299	308	317	326	335	376	384	402	410	428
30	220	229	237	246	255	289	298	307	315	324	363	371	388	396	413
35	213	221	229	238	247	280	288	296	305	313	349	357	374	382	397
40	206	214	222	230	238	270	278	286	293	301	335	343	358	365	380
42	203	211	219	227	235	266	273	281	288	296	329	337	351	358	373
44	200	208	216	224	231	251	259	276	284	291	323	330	344	351	365
46	197	205	213	220	228	257	264	271	279	286	317	324	337	344	357
48	195	202	209	217	224	253	260	267	274	280	311	317	330	337	349
50	192	199	206	213	220	248	255	262	268	275	304	310	323	329	341
53	189	196	203	210	217	244	250	257	263	270	297	303	315	321	333
54	188	193	199	206	213	239	245	252	258	264	291	296	308	313	324
56	183	189	195	202	209	234	240	246	252	258	284	289	300	305	315
58	179	186	192	199	205	229	235	241	247	252	277	282	292	297	306
60	178	185	191	196	201	225	230	236	241	247	270	274	284	289	298
62	173	179	185	191	197	220	225	230	236	241	262	267	276	280	289
64	170	176	182	188	193	215	220	225	230	235	255	260	268	273	280
66	167	173	178	184	189	210	215	220	224	229	248	252	260	264	271
68	164	169	175	180	185	205	210	214	219	223	241	245	252	256	262
70	161	166	171	176	181	200	204	208	213	217	234	238	244	248	254
72	157	162	167	172	177	195	199	203	207	211	227	231	237	240	246
74	154	159	164	169	173	190	194	198	202	205	220	223	229	232	238
76	151	156	160	165	169	185	189	193	196	200	214	217	222	225	230
78	148	152	157	161	165	180	184	187	191	194	207	210	215	217	222
80	145	149	153	157	161	176	179	182	185	188	201	203	208	210	215
82	142	146	150	154	157	171	174	177	180	183	195	197	201	203	207
84	139	142	146	150	154	167	169	172	175	178	189	191	195	197	201
86	135	139	143	146	150	162	165	168	170	173	183	185	189	190	194
88	132	136	139	143	146	158	160	163	165	168	177	179	183	184	187
90	129	133	136	139	142	153	156	158	161	162	172	173	177	178	181
92	128	130	132	135	138	149	152	154	156	158	166	168	171	173	175
94	124	127	130	133	135	145	147	149	151	153	161	163	166	167	170
96	121	124	127	129	132	141	143	145	147	149	156	158	160	162	164
98	118	121	123	126	128	137	139	141	143	145	151	153	155	157	159
100	115	118	120	123	125	134	136	137	139	140	147	148	151	152	154
102	113	115	118	120	122	130	132	133	135	136	143	144	146	147	149
104	110	112	115	117	119	126	128	130	131	133	139	139	142	142	144
106	107	110	112	114	116	123	125	126	127	129	134	135	137	138	140
108	105	107	109	111	113	120	121	123	124	125	130	131	133	134	136

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